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Catalysis in an Aberration-free Environment: Atomic Resolution Studies of *in situ* Water Splitting

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We have successfully imaged the Cu precipitates in $Ce_{1-x}Cu_xO_2$ during an H_2 annealing cycle. The $Ce_{1-x}Cu_xO_2$ system has immediate applications in the low temperature steam reforming of hydrogen from hydrocarbon fuels via the water-gas shift reaction (CO 1 H_2O → H_2 1 CO_2). These are the first results obtained from the FEI Titan environmental transmission electron microscope (TEM) at Brookhaven National Laboratory, which is capable of atomic resolution at pressures up to 10 torr and temperatures of up to 700°C. We have found the precipitates to be 10–15 nm in size, which is 5–10 times larger than anticipated. During the subsequent oxygen anneal, it was found that the Cu precipitates do not return to the bulk $Ce_{1-x}Cu_xO_2$ phase in solid solution as suggested by prior synchrotron diffraction and extended X-ray absorption fine structure (EXAFS) results, but instead form an amorphous oxide at the surface of the particles. We will also present *in situ* data from the $Pr_xCa_{1-x}MnO_3$ system in a water vapor environment, which is among the most active oxygen evolution catalysts for electrochemical water splitting. Using our *in situ* imaging capabilities, we have identified which regions of the catalyst particles are most active for oxygen evolution and have found that some phases exhibit almost no activity.